Where is your Guardian Angel?
Locating and Protecting Vulnerable Road Users

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DLR


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ZONE

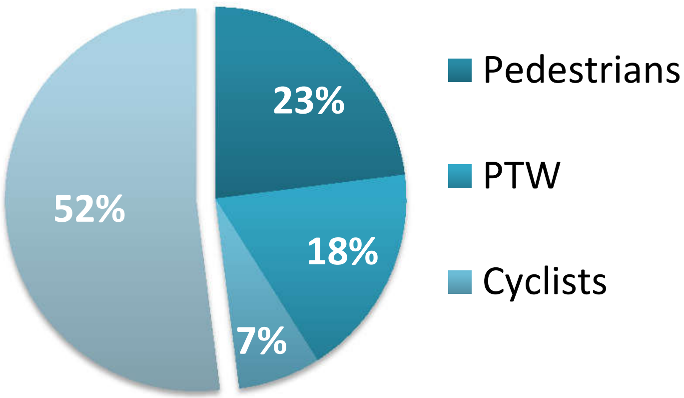
VRU Accident Statistics

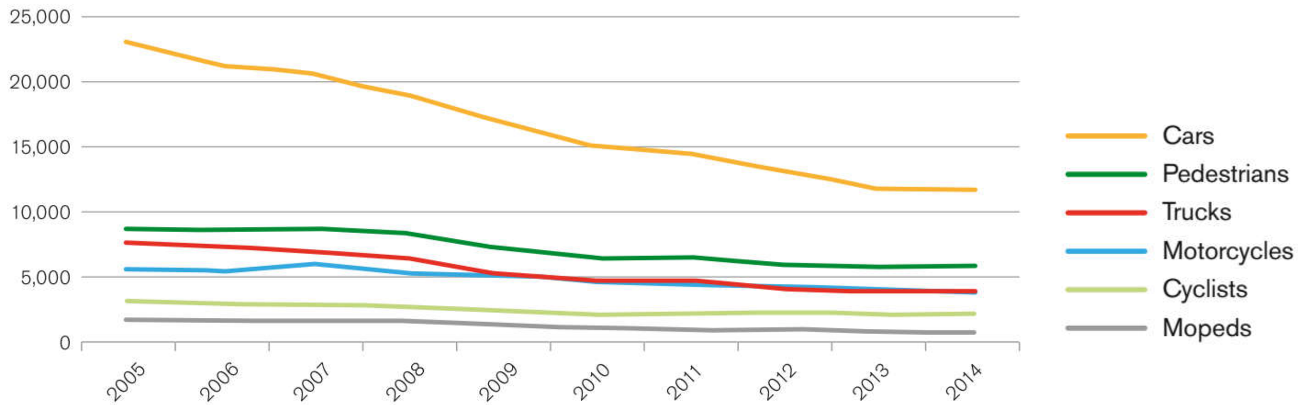

motojektif.com

Vulnerable Road Users

- On European roads:
  - Around 28.000 fatalities and 250.000 serious injuries every year
  - VRUs comprise 46% of all fatalities

Traffic accidents in Europe

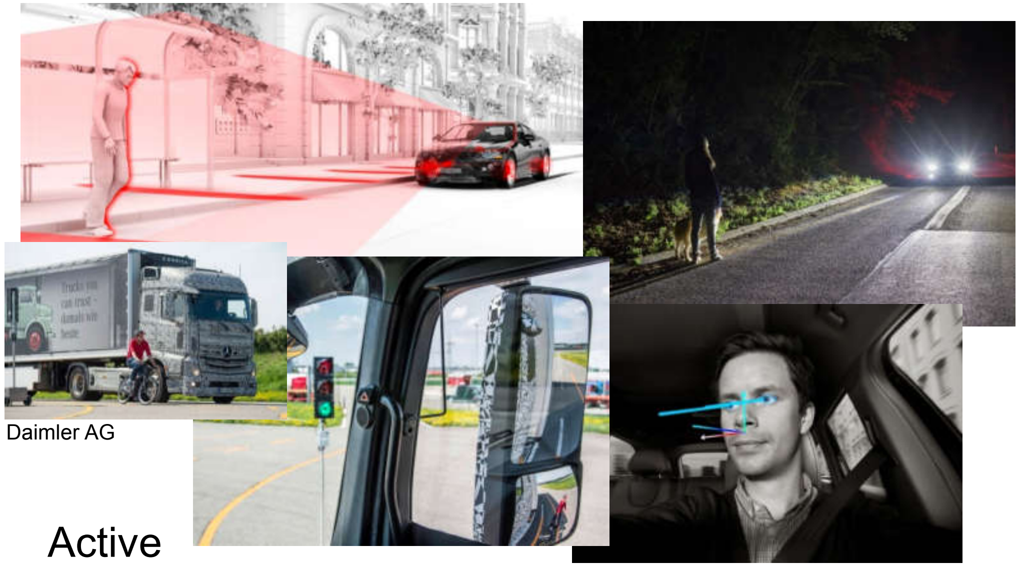




Source: European Commission, (2016). Annual Accident Report, European Commission, Directorate General for Transport, June 2016

VRU Protection

Passive



Daimler AG

Active

Infrastructure

SenUVK, Bloomimages

lighting.eu

Bike-Flash / MRS Mobile Road Safety GmbH & Co. KG

Engineering &Technology

Collision Detection/Avoidance Algorithms

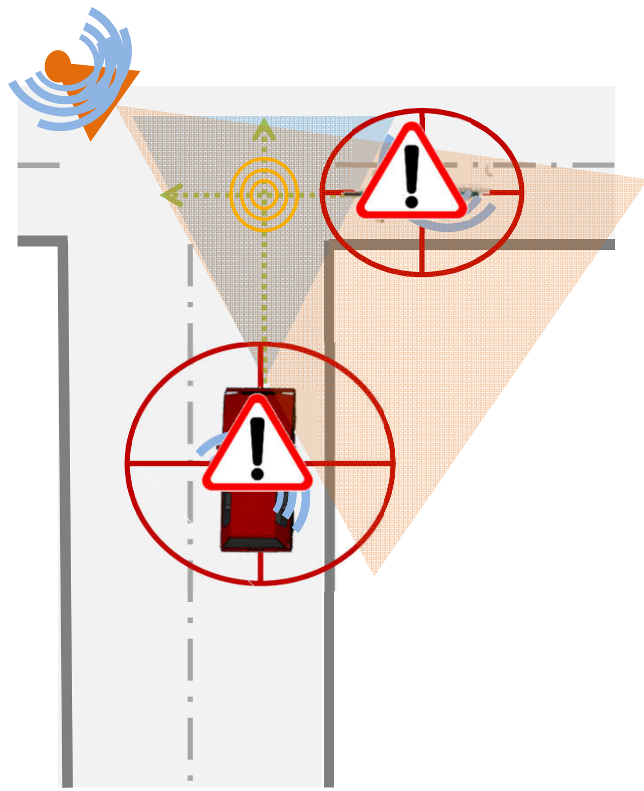
Warning	Motion Control

Collision Detection

Trajectory prediction

Map

Perception	Communication	
	Localization	Infrastructure



Increase awareness:
- → Robustness
- → Reliability
- → Minimize false detections and mis-detections
- → Minimize the number of warnings

Cooperative Awareness

Communication & Localization

New Approaches for VRU Protection

Infrastructure -based Detection

VRU in-vehicle Perception

Smartphones

- Increased computational power
- Build-in sensors:
  - GNSS
  - Inertial and magnetic
  - Sound and light
- Built-in communication:
  - Wireless communication: WiFi and V2X (ITS-G5 / DSRC)
  - Cellular communication: LTE, 5G
  - Short-range: BLE
- Build-in HMI: visual, haptic and acoustic

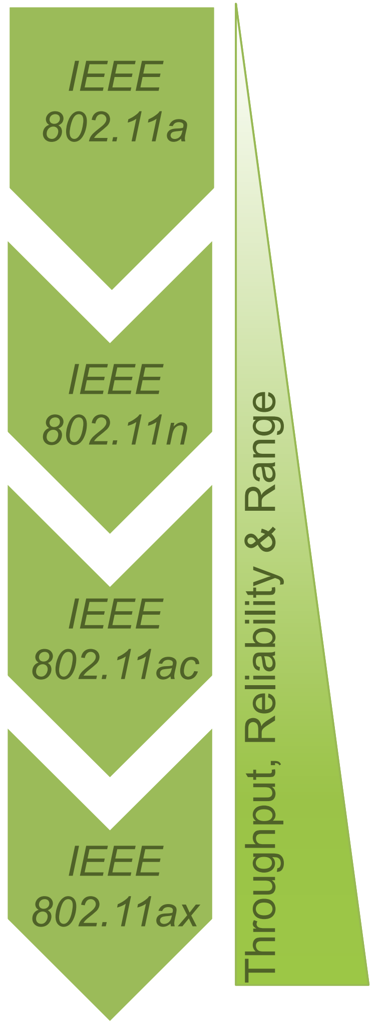
V2X Communication

- **ITS-G5 / DSRC**: Ad-hoc communication via IEEE 802.11p
- **LTE-V2x**: September 2016: Release 14 enables LTE-V2X over sidelink (PC5)
- **5G-NR**: Release 15 in Q3 2018 is already including the first 5G standards.

- Communication impairments:
  - Physical - Layer
    - Low signal level (attenuation, shadowing / LoS-blockage or Interference)
    - Non-ideal channel propagation (multipath, fading, Doppler, etc.)
  - Medium Access – Layer
    - Packet collisions (e.g. due to hidden terminal)

IEEE 802.11 Study Group: Next Generation Vehicle-to-X (NGV)

- Aim: PAR until September 2021
  - Twice the throughput as 802.11p, 500km/h relative speed, 3dB lower sensitivity, ranging / positioning, mmWave @ 60 GHz
  - Backward compatibility and coexist with 802.11 – 2016 (802.11p)
- Discussions:
  - Use-cases: BSM, sensor sharing, MCO, Infrastructure Com (IoT, High-data rates data offloading), vehicular positioning, automated driving, aerial vehicle ITS
  - Improved communication performance through:
    - Channel Coding: error correction messages, outer Reed-Solomon Codes, downclocking
    - Simulation: Common Doppler
  - Ranging, mm-Wave, etc.



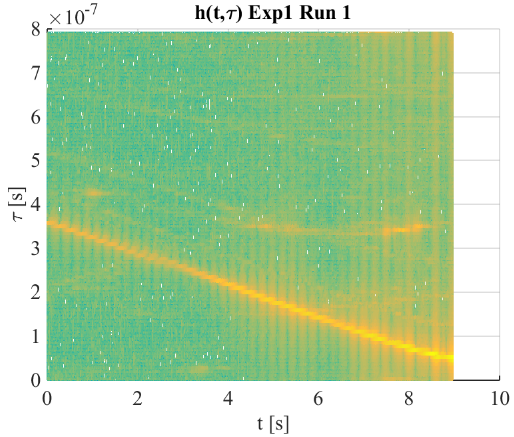
Vehicle-to-Pedestrian Communication

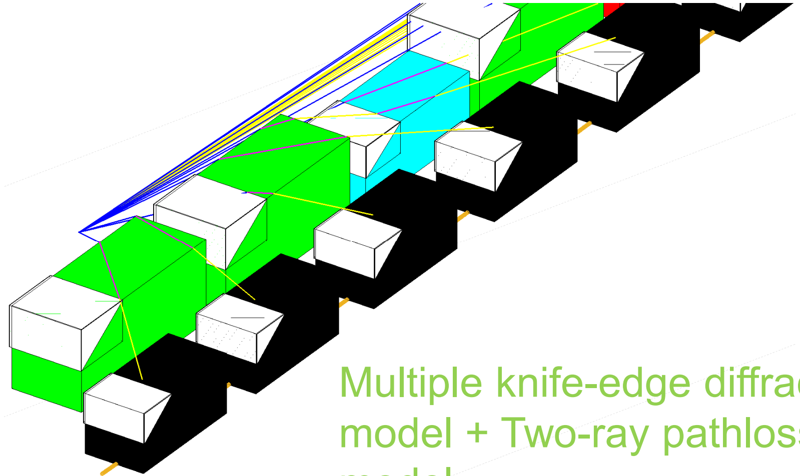
- Reliable vehicle-to-pedestrian communication (V2P):
    - Knowledge about propagation conditions
    - Accurate V2P channel model for critical situations
        - For communication system design (channel estimation, channel coding, etc.)
        - For evaluation in simulated test environments

RX

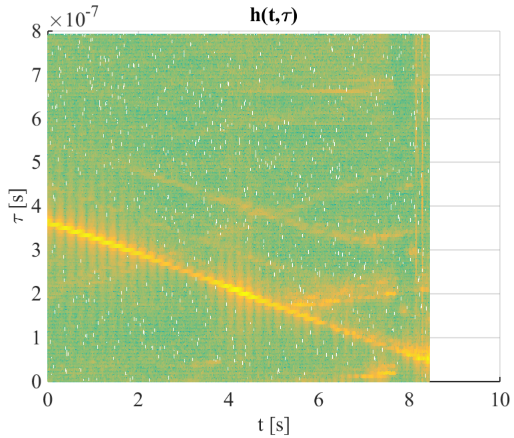
TX

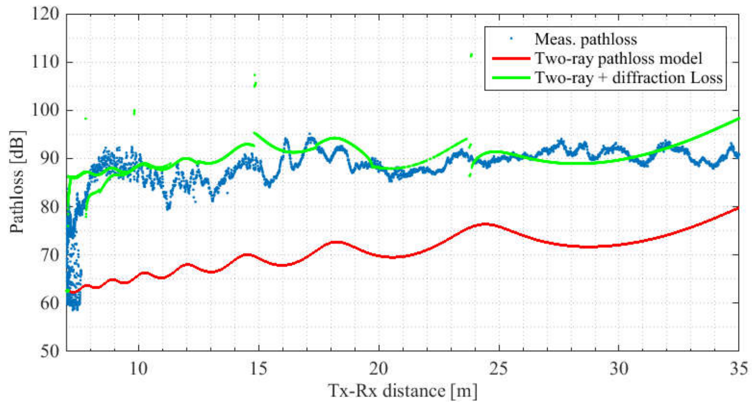
V2P Channel Modeling





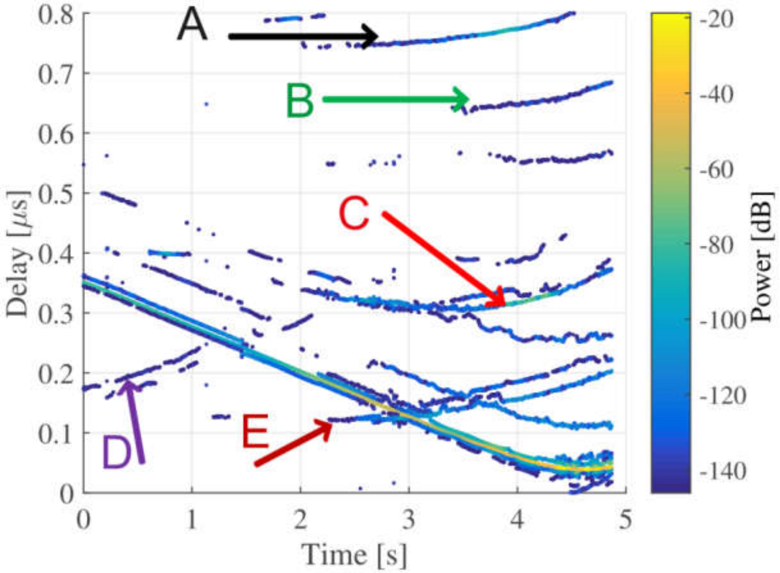
Multiple knife-edge diffraction model + Two-ray pathloss model

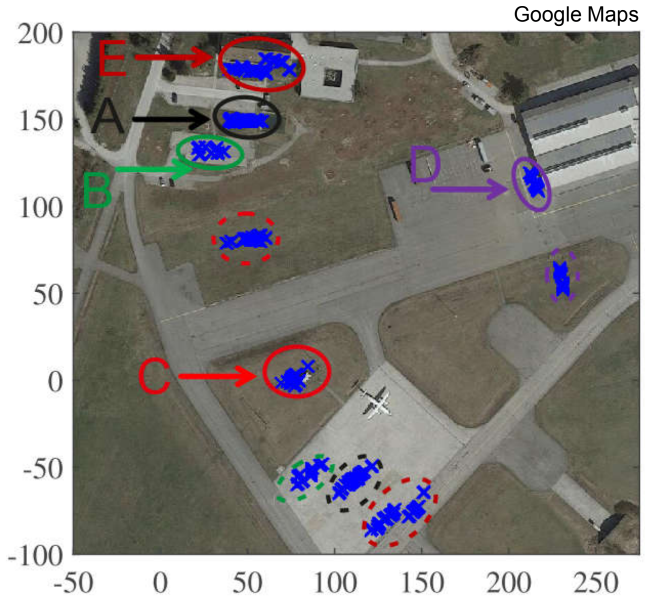




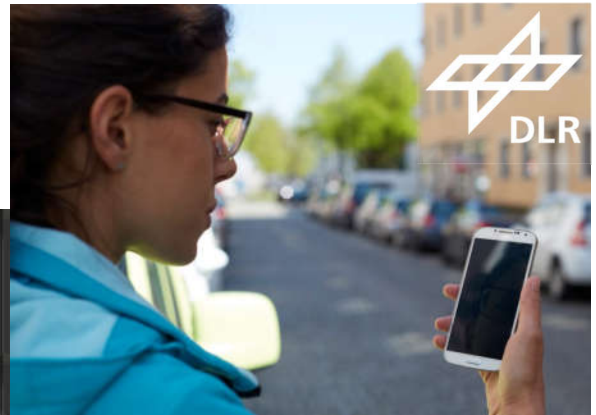
Source: Rashdan, Ibrahim und Ponte Müller, Fabian und Wang, Wei und Schmidhammer, Martin und Sand, Stephan (2018) *Vehicle-to-Pedestrian Channel Characterization: Wideband Measurement Campaign and First Results.* EuCAP 2018, 9.-13. Apr. 1018, London, UK.

Steps towards a V2P Geometric-based Stochastic Channel Model

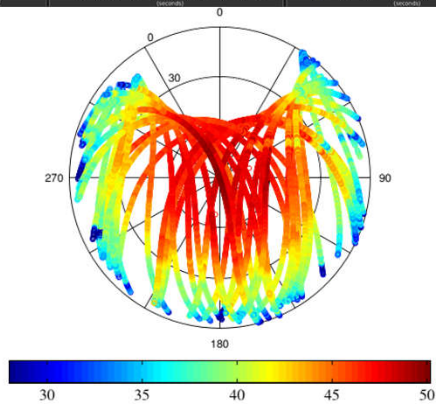




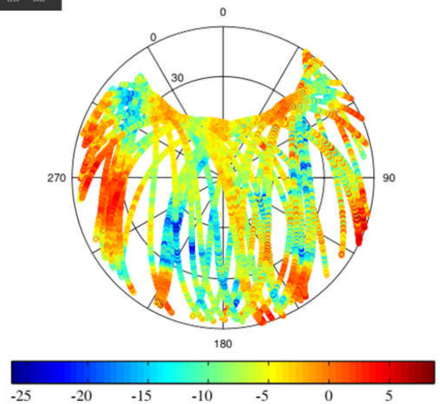
VRU Localization – GNSS in Smartphones



- Assisted GNSS
- Differential GNSS
- Broadcom BCM47755 dual-frequency GNSS receiver chip for smartphone
- Google announces supporting raw GNSS measurements from Android N on
- Challenges:
  - GNSS antenna (backplane, shielding, etc.)
  - TCXO
  - Location and orientation



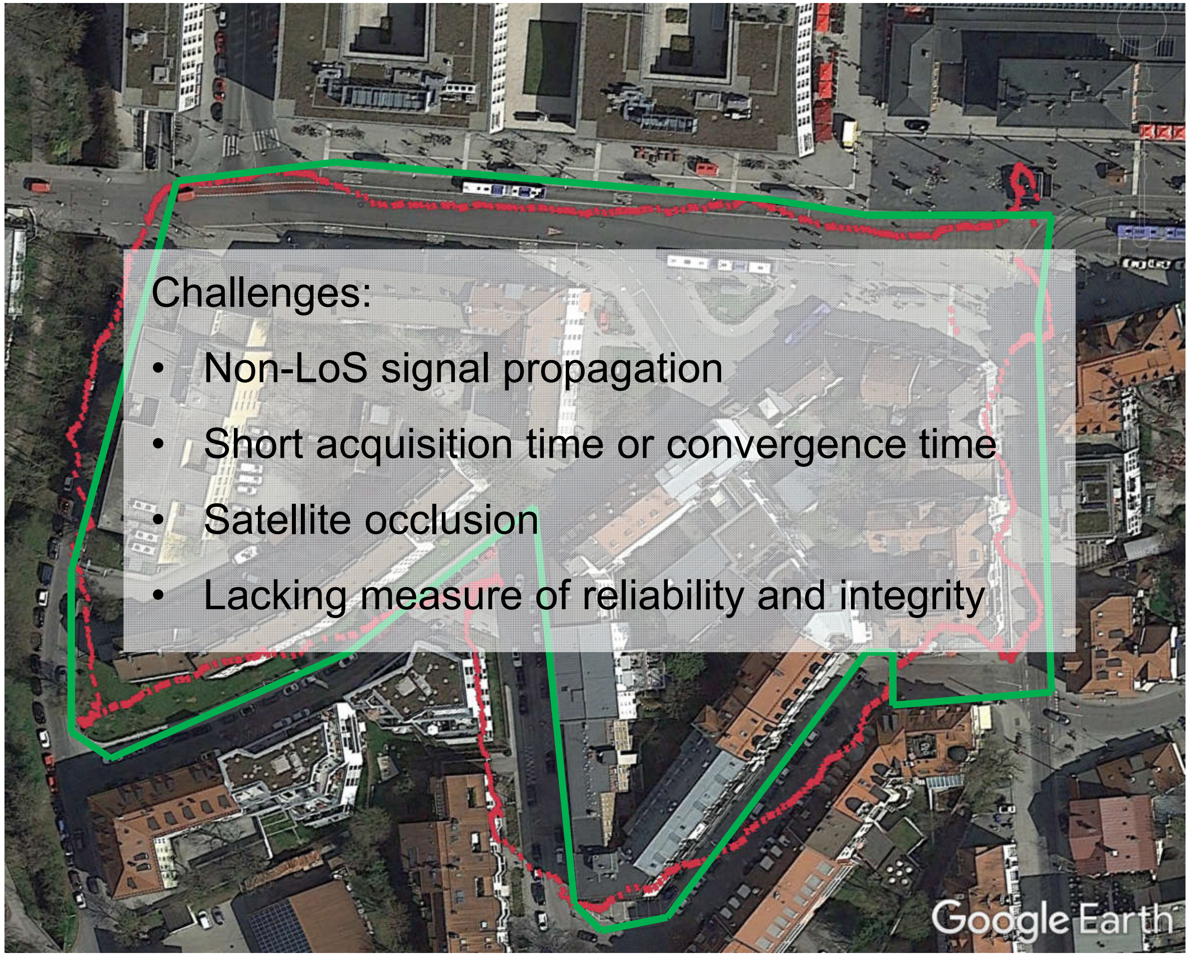
Navigation grade GNSS antenna



Galaxy S6 smartphone antenna

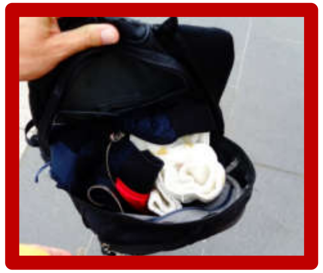
T. E. Humphreys et al. , "*On the feasibility of cm-accurate positioning via a smartphone's antenna and GNSS chip*," *2016 IEEE/ION Position, Location and Navigation Symposium (PLANS)*, Savannah, GA, 2016, pp. 232-242.

VRU Localization – GNSS in Smartphones



Challenges:

- Non-LoS signal propagation
- Short acquisition time or convergence time
- Satellite occlusion
- Lacking measure of reliability and integrity



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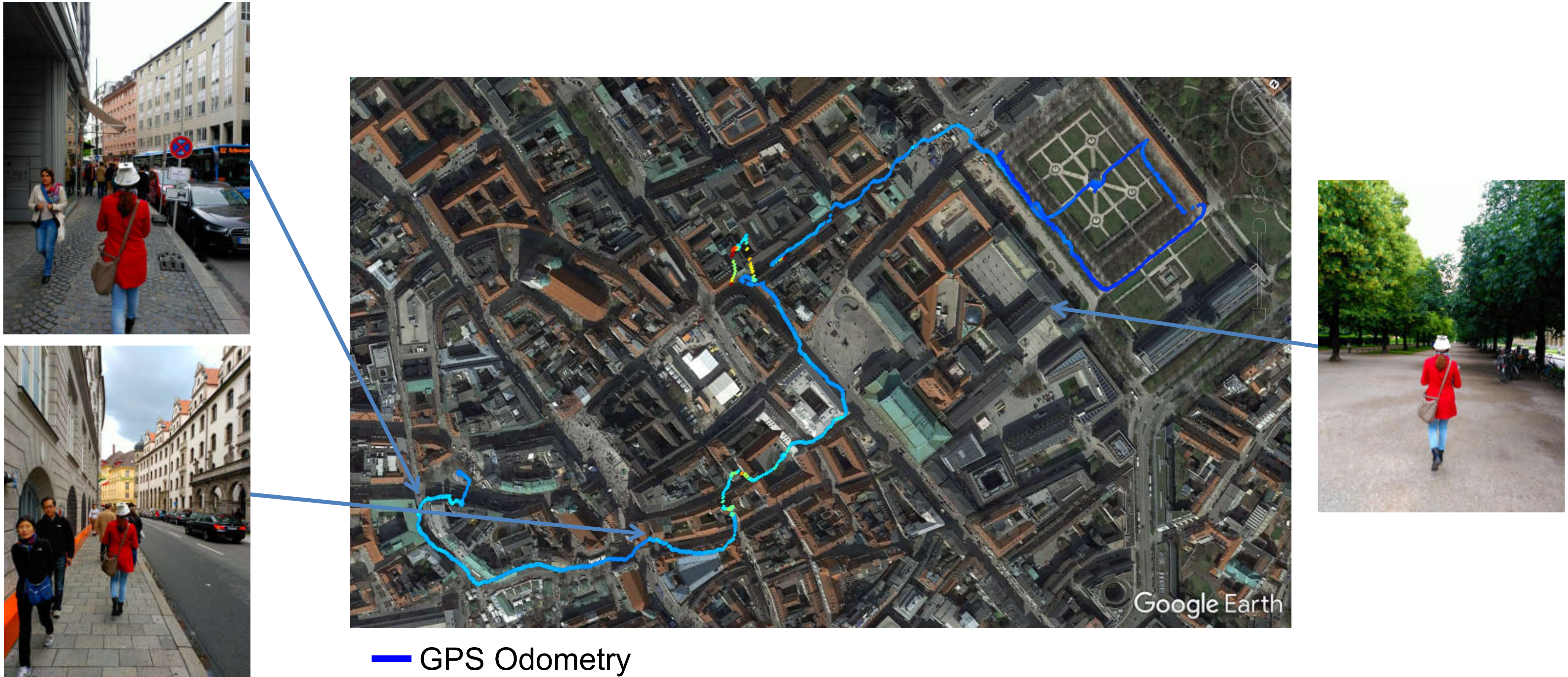
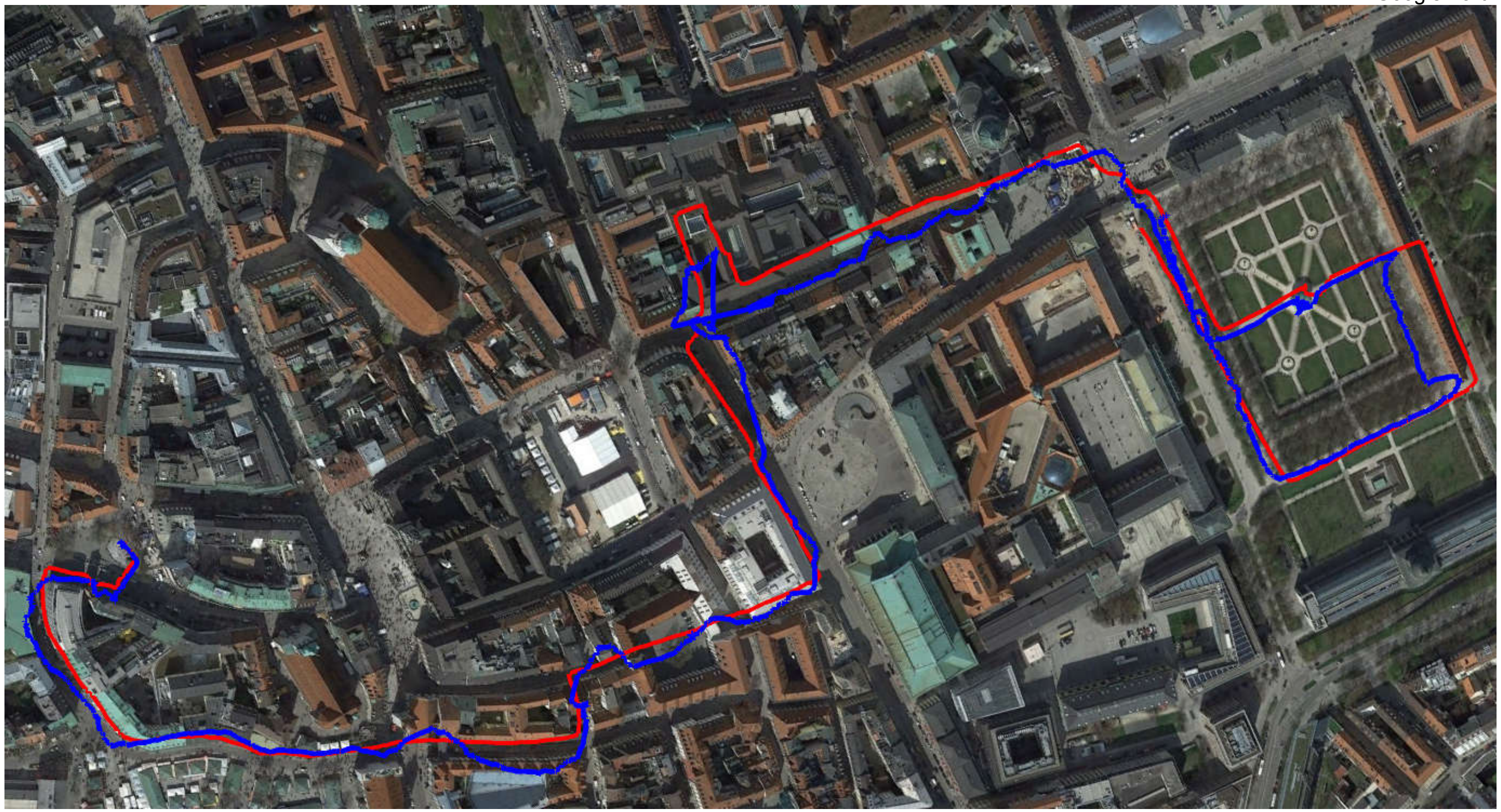
Urban Pedestrian Localization with GNSS and IMU

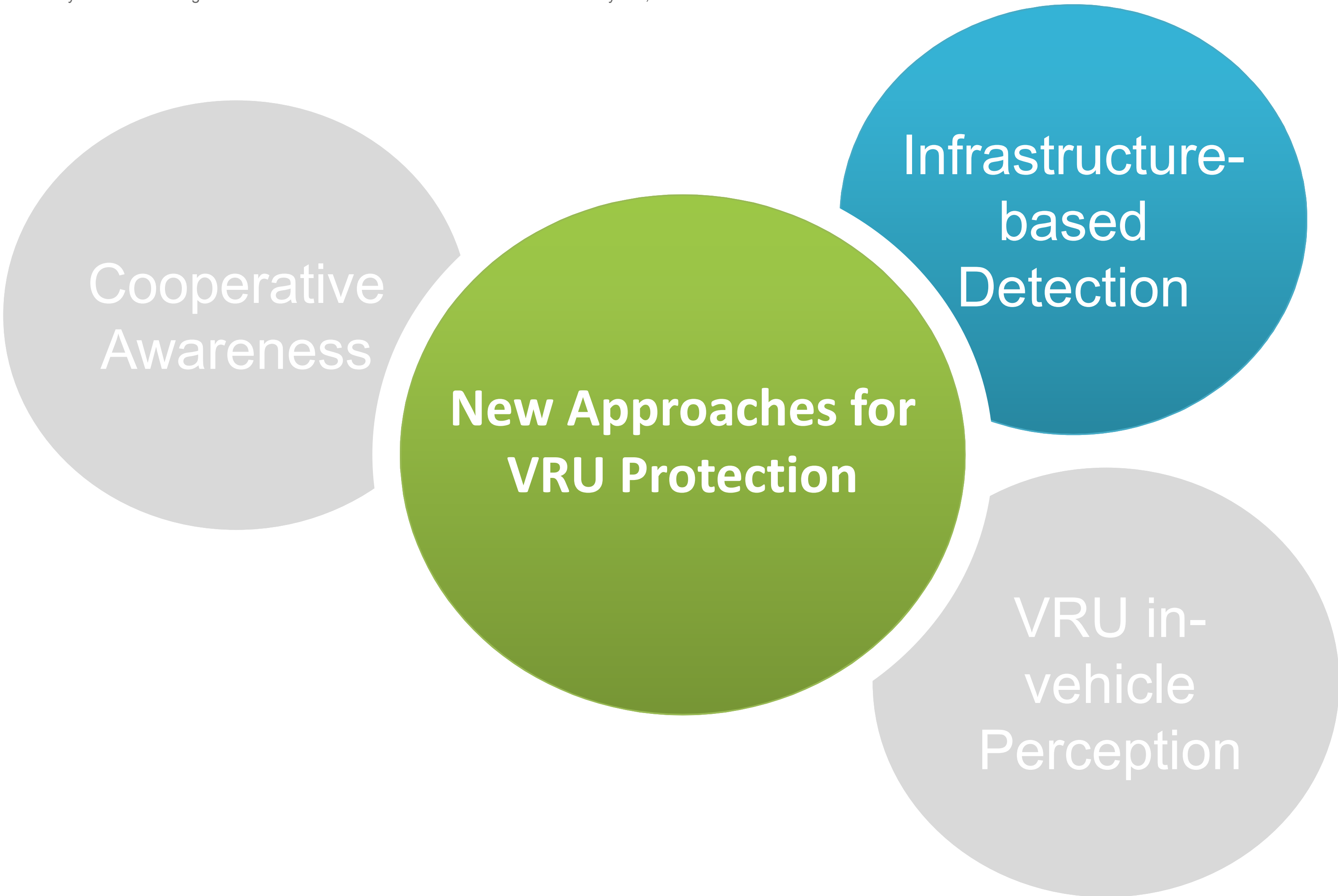


Urban Pedestrian Localization with GNSS and IMU

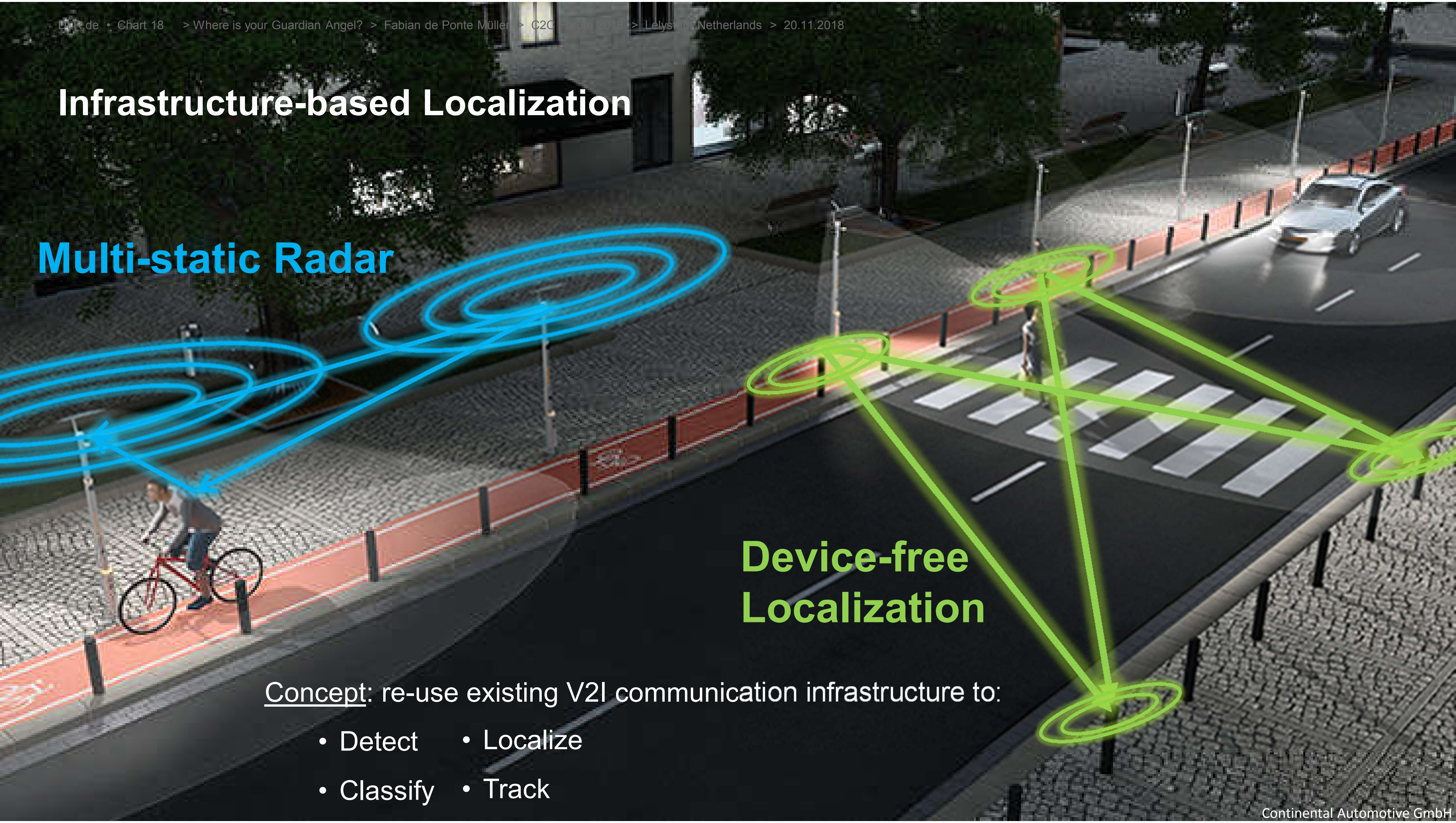
Google Earth



GPS Odometry   Pocket-based IMU Odometry with compensated Drift


Cooperative Awareness
New Approaches for VRU Protection
Infrastructure-based Detection
VRU in-vehicle Perception

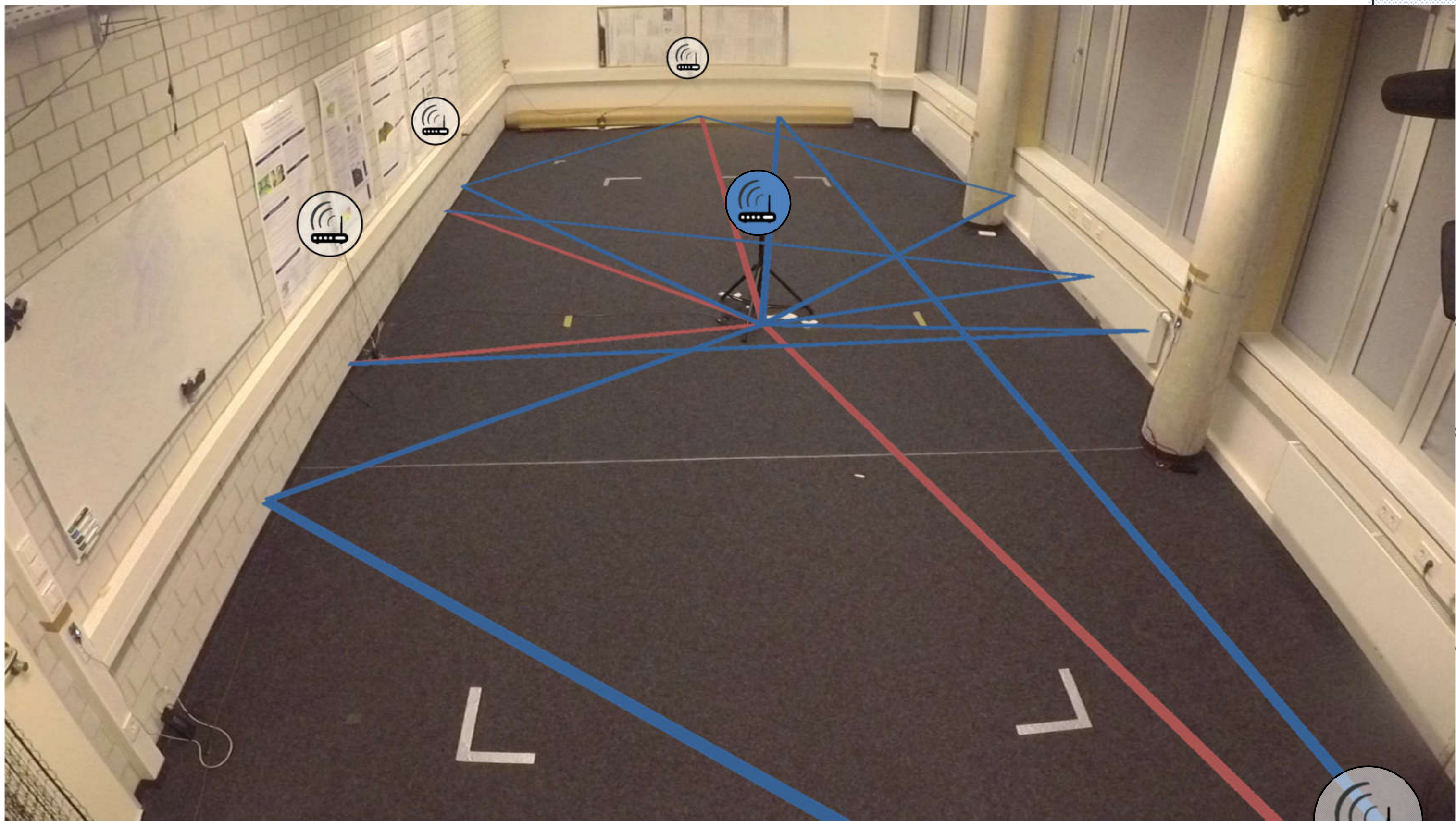
Infrastructure-based Localization

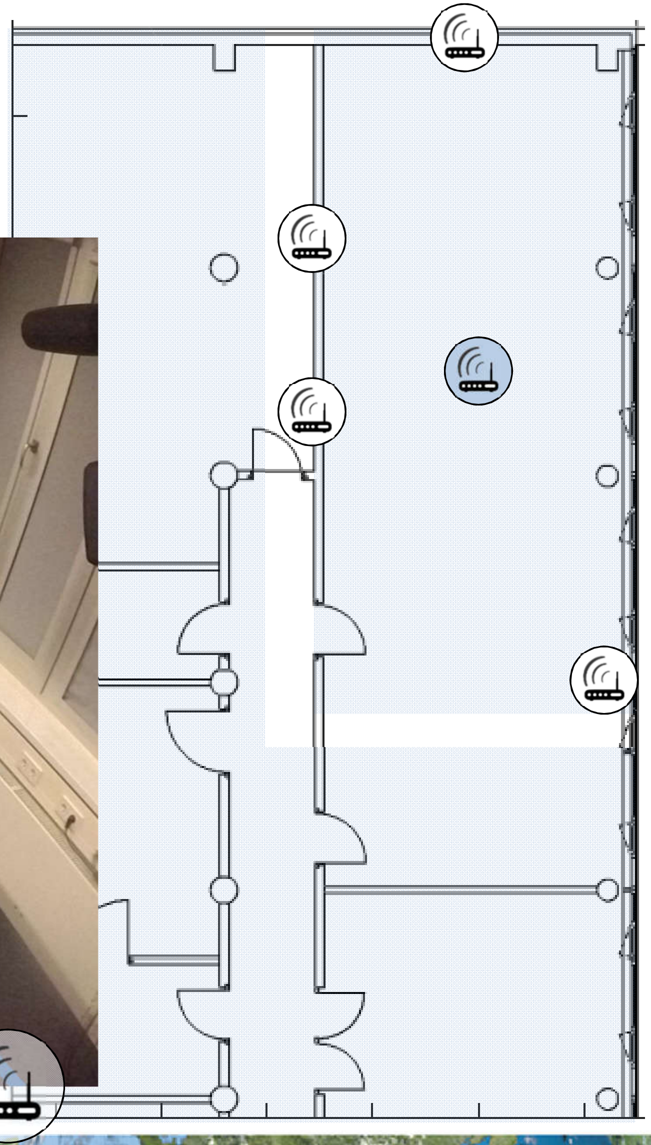


Concept: re-use existing V2I communication infrastructure to:

- Detect
- Localize
- Classify
- Track

Device-free Localization and tracking



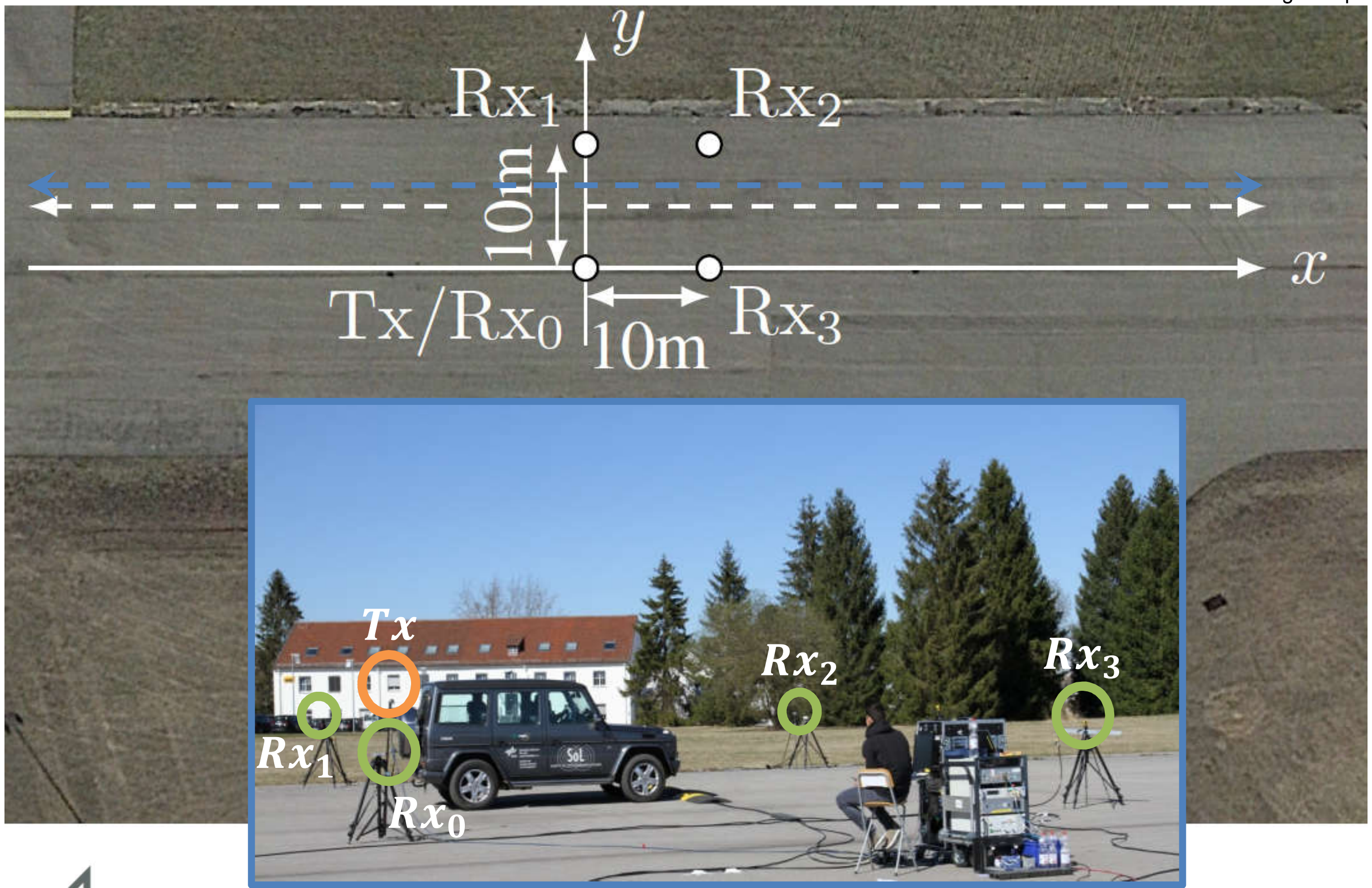


Device-free localization and tracking

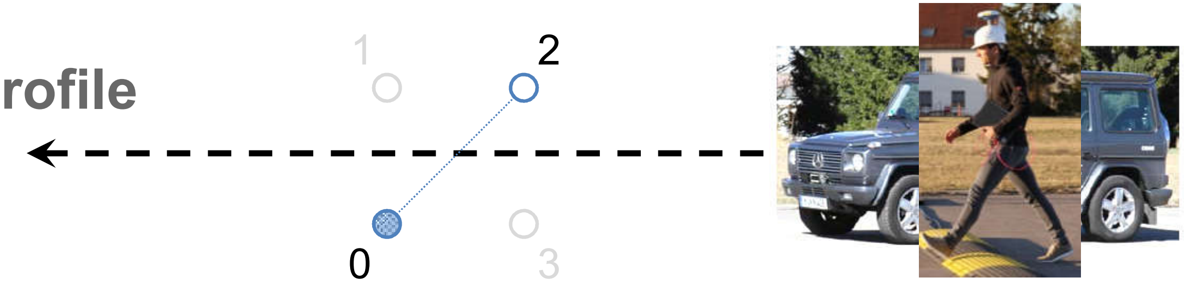
M. Schmidhammer, C. Gentner *A Novel Approach of Passive Localization for Indoor Positioning,* Presented at ION GNSS+ 2018, Miami, Florida

Multi-static Radar – Measurement Campaign

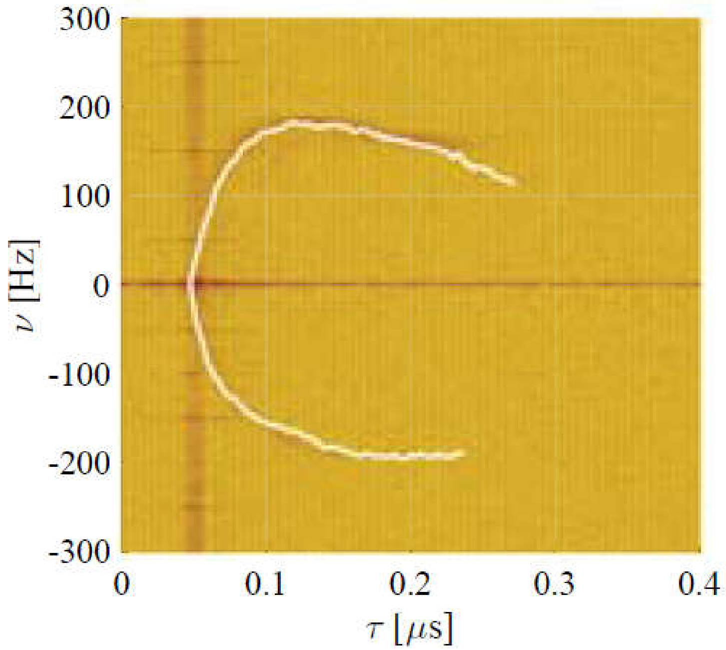
Google Maps



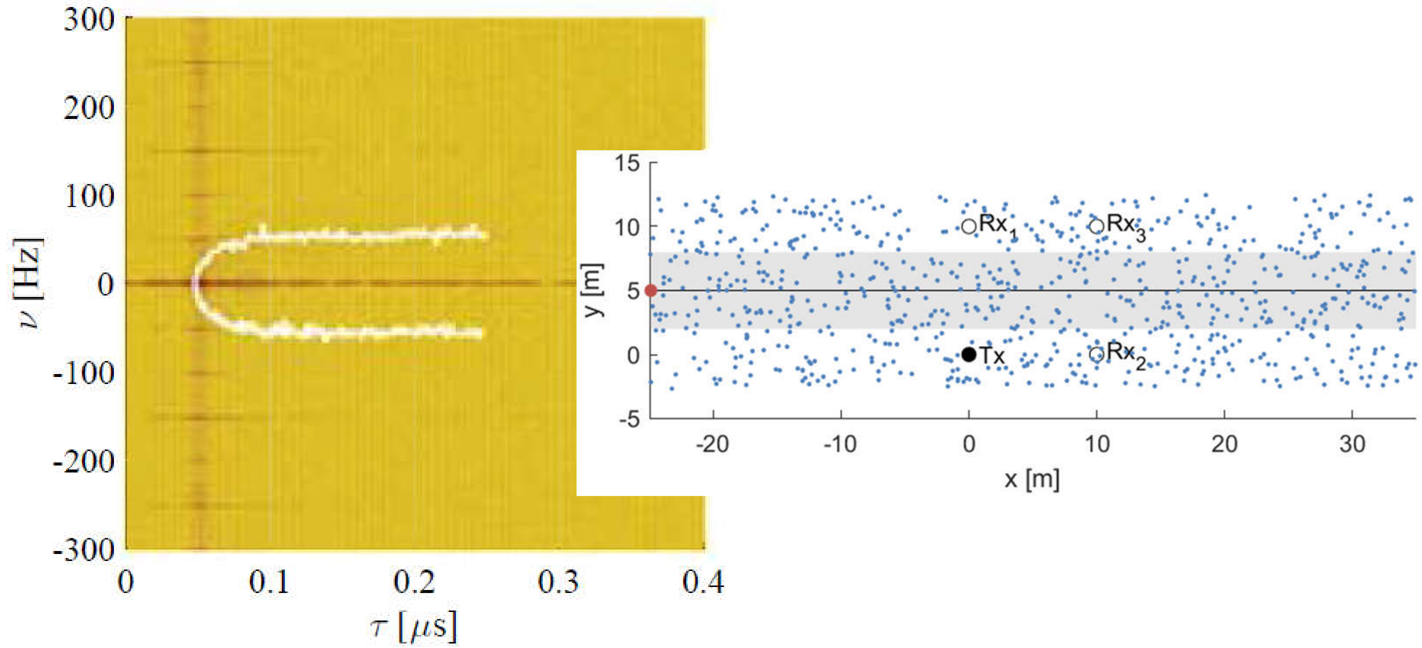
Multi-static Radar - Delay-Doppler Profile



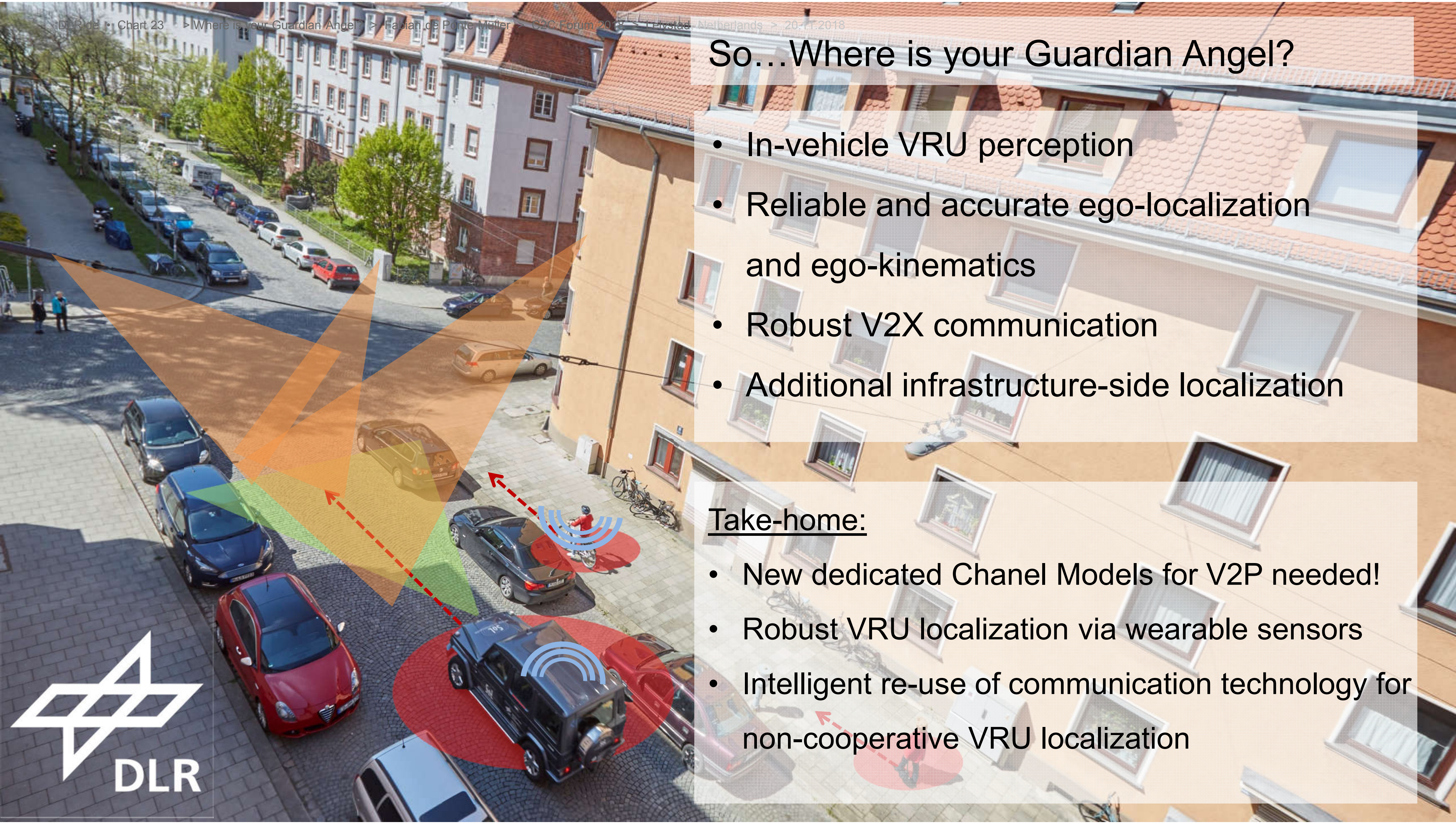
Vehicle



Pedestrian



Source: Schmidhammer, Martin und De Ponte Müller, Fabian und Sand, Stephan und Rashdan, Ibrahim (2018) *Detection and Localization of Non-Cooperative Road Users based on Propagation Measurements at C-Band*. 12th European Conference on Antennas and Propagation (EuCAP), London, Great Britain.



So…Where is your Guardian Angel?

- In-vehicle VRU perception
- Reliable and accurate ego-localization and ego-kinematics
- Robust V2X communication
- Additional infrastructure-side localization

Take-home:

- New dedicated Chanel Models for V2P needed!
- Robust VRU localization via wearable sensors
- Intelligent re-use of communication technology for non-cooperative VRU localization

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